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Dental Destruction in Broken-Hill Man

The determination of the type of Broken-Hill man's diet by the study wear on occlusal surfaces may be complemented by the examination of striations left by the diet on the dental crown. Microscopic grooves of dental buccal surfaces yields new data as to what prehistoric man ate. It is suggested that Broken-Hill man allowed the development of rampant caries through his ignorance of the use of tooth picks.

1. Introduction

The earliest evidence of human dental caries comes from a sample found in 1921 during the exploitation of a zinc mine at Broken-Hill in Northern Rhodesia (Zambia). A human skull was discovered bearing a mixture of Pithecanthropine and Neanderthaloid morphological characters (Murrill, 1975). The skull has been dated by the racemization of aspartic acid method giving an age of 110,000 years B.P. (Bada *et al.*, 1974). This date fits well with the archaeological and geological contexts.

The teeth of the skull are, as a result of rampant caries, in an advanced state of decay. The skull is unique in this respect, and has caused much theoretical discussion, since dental disorders of this type are commonly considered to be very recent, and related to the appearance of agriculture in the sixth millennium B.C. (Plate 1).

This article attempts to further this discussion, and our understanding of the emergence of dental caries in man, by the study of microscopic abrasions and striations on the surface of the dental crowns. The underlying principle of the method is that different wear patterns can be identified and related to different wear processes.

2. Morphological Characteristics of the Upper Jaw, the Palate, and the Teeth

The maxillary alveolar arcade is of "U" shaped form with a length of 70 mm (between the inter-incisal point and the middle of the tangent straight line across the distal face of the alveolar processes), and a maximum width of 83.5 mm. The molars are strongly affected by hyperostosis on the buccal surfaces, while the palate is lightly and irregularly affected. The alveolar depth, 37 mm between the subnasal and inter-incisal points, shows strong prognathism. As this is related to the length of the tooth roots, the length

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of the root of canine 23 was measured, giving 24.8 mm which might be the length of a present day white man's canine. The vault of the palate is high, being 19 mm at the second molar and 25 mm if measured from the level of the neck of the second molars.

All the teeth have erupted and are distributed very regularly over the arcade, but the decay due to caries is very marked. There is no dental gigantism, but the dimensions of the teeth correspond with those of the dental arcade with $M1 > M2 > M3$. The degree of decay of the dental crowns is too advanced to allow their measurement except at the neck of the teeth. Some measurements are given below, but the values should be treated with caution given the problems encountered.

Dental arcade length: 62 mm
 Anté-molar length: 29 mm
 Molar length: 33 mm
 External bi-canine width: 54 mm
 Internal bi-canine width: 33 mm
 External bi-M2 width: 77.5 mm
 Internal bi-M2 width: 50 mm
 External bi-M3 width: 76 mm

Dimensions of the teeth:

11 crown	—	—	21 crown	—	—
neck	M-D 8.2 mm	B-L 8.4 mm	neck	M-D 8.2 mm	B-L 8.4 mm
12 crown	—	—	22 crown	—	—
neck	—	—	neck	M-D 7 mm	B-L 8 mm
13 crown	—	—	23 crown	M-D 10 mm	B-L 11 mm
neck	M-D 7.9 mm	B-L 10.2 mm	neck	M-D 8 mm	—
14 crown	—	—	24 crown	M-D 8 mm	B-L 11 mm
neck	M-D 7.2 mm	B-L 11 mm	neck	M-D 7 mm	B-L 10.5 mm
15 crown	—	—	25 crown	—	—
neck	M-D 5.1 mm	B-L 9.7 mm	neck	M-D 5.7 mm	B-L 9 mm
16 crown	—	B-L 13 mm	26 crown	—	—
neck	M-D 10 mm	B-L 13.5 mm	neck	M-D 11 mm	B-L 13.8 mm
17 crown	M-D 11.8 mm	B-L 13.6 mm	27 crown	M-D 12 mm	B-L 14 mm
neck	M-D 9.4 mm	B-L 13.2 mm	neck	M-D 10 mm	B-L 13 mm
18 crown	—	—	28 crown	M-D 10 mm	B-L 12.5 mm
neck	M-D 7 mm	B-L 13 mm	neck	M-D 7 mm	B-L 12 mm

All except five teeth are affected by caries and only a small part of the crown remains on half of them, the caries appear to have developed from the inter-dental spaces. For the five teeth it is difficult to assess the extent of caries as 12 is missing, 13 and 14 are broken, and 11 and 21 are very worn.

Pathological alveolar recession affects the whole dentition. In addition there is osseous lysis due to dental abscesses involving 22, 26, 27 and 28.

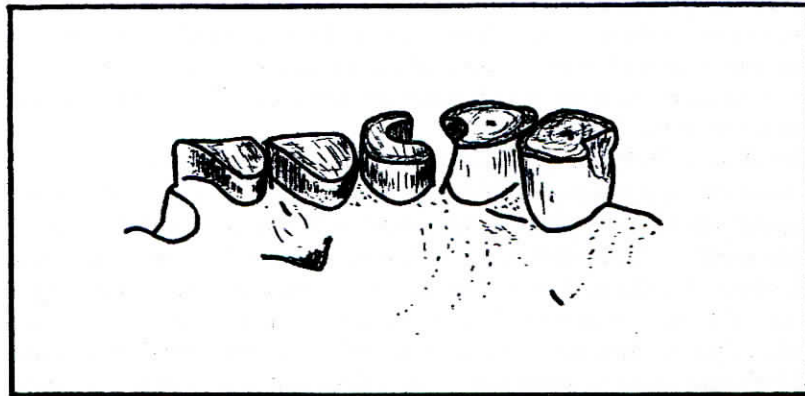
3. Dental Wear

The wear on enamel and/or exposed dentine varies over the dental arcade and provides a useful indication of the distribution and relative value of the forces to which the teeth of Broken-Hill man were subjected.

The degree of wear of the grinding surfaces of the teeth is progressive from the incisor to M3, the front teeth being considerably more worn than the back teeth. The molars are least worn and, taking into consideration the fact that the teeth are slightly inclined

their wear is horizontal. The premolar is slightly more worn, also in the horizontal plane, whereas the wear surface on the canines is oblique, running from the incisal edge to the neck of the crown and from buccal to lingual surface (Figure 1). The crown of the lateral incisor (22) is very reduced, but rather than being simply oblique, the wear surface is also lingually convex. The central incisors are worn in the same way and preserve only a slight vestibular ridge of enamel surrounded by erosion at the neck of the tooth.

Figure 1. The premolars and molars are worn in the horizontal plane, whereas the wear surfaces of the incisors are lingually convex and much more reduced.



This type of wear differs radically from that normally seen in human teeth. The usual wear pattern is often in direct relationship to the sequence of tooth eruption, the sequence determining the distribution of forces applied to the dental arcade. Thus in normal conditions, and with a sufficiently abrasive diet, the time interval between the eruption of M1 and M2 allows the dentine of M1 to be exposed before an adequate crushing surface has been established by the molars and premolars. The eruption sequence thus gives a normal wear predominance to M1, the degree of wear decreasing both forwards and backwards from this tooth.

This normal wear pattern may be affected by various factors such as the diet and its method of preparation, and individual or cultural preferences. The modifications to the standard wear pattern seen in Broken-Hill man help in the understanding of his particular pathological conditions which include caries in the buccal cavity (lysis of the alveolar bone, and dental abscesses, as well as mastoiditis, and a circular hole in the temporal bone) for which no valid explanation has yet been put forward.

From work on African monkeys (Lavelle, 1975) on convex wear patterns in the incisors it can be suggested that Broken-Hill man probably peeled the skins of certain roots and young shoots by pulling these away from the mouth across the lower and upper incisors. The severe wear thus produced on the front teeth would not permit a cutting action except on the edges of the back teeth; the efficiency of the jaws would be considerably reduced forcing this individual to rely on a diet of soft foods. Chronic gingivitis established would have provoked a lysis of the supporting tissues of the tooth, offering numerous food traps. Subsequently responsible for the appearance of the inter-dental caries.

However, as an alternative mechanism, the relationship between condyle, eminence contact and occlusal loading should not be forgotten as this can transfer the main force away from M1 to the incisors: this jaw mechanism is well known by gnathologists since the first publication by Campbell in 1925.

4. Microscopic Features of the Enamel Surfaces

The role of the diet in the alteration of dental surfaces has often been studied since Butler (1952) deduced the operational details of the movement of the lower against the upper teeth, on the basis of the distribution of wear facets on the contact surfaces of the crowns. This type of wear is due to attrition, the mutual rubbing of one surface against another. Subsequently Welsch (1967), then Kay & Hiemae (1974) deduced the details of the mastication process based on the study of striations on the cutting facets visible on the teeth of certain monkeys which have an exclusive diet; such as the colobus monkey which feeds on the leaves of trees.

For Molnar & Ward (1977) the crucial point in these studies was the recognition that wear on the occlusal surfaces represents the degree of effort produced in mastication. Thus, although it is established for instance that small, hard food particles lead to important wear of the molars and premolars, it is not possible to interpret the degree or distribution of occlusal wear without knowing the exact age of the subjects as well as the method of food preparation. These researchers have studied grooves on the grinding surfaces of the teeth in order to understand jaw movements during mastication.

The present study examines grooves and striations on the lateral surfaces of the teeth in particular as a means of analysing the diet, as it is probable that the numerous abrasive particles contained in the diet of prehistoric man left traces of their functional history.

It is assumed that in the short term the consistency of the ingested material is a determining factor in the behaviour of the mouth, and that the numerous abrasive particles in the diet of prehistoric man marked the surfaces of the teeth, leaving evidence of their functional history.

In a previous study (Puech, 1975), it was found that by analysing the length and direction of grooves on the vestibular surfaces of the teeth of prehistoric man, from the Acheulean to the Bronze Age, it was possible to trace the decline of hunting relative to the progressive adoption of agriculture. The teeth of Broken-Hill man were studied in this manner, from photographs of the dental enamel at a magnification $\times 50$. The orientation of the microscopic striations was plotted, placing the total length of the grooves in any one direction on a star diagram (Plate 2, Figure 2), the degree of inclination varying from 45° to 45° . The average length of the striations was added to complete the description of the grooves. The state of wear of the dental crowns only allowed this analysis for tooth 16, the first right hand molar. The results obtained indicate that the striations on the teeth of Broken-Hill man are similar to those known from the analysis of Hortus Neanderthal hunter's teeth, 55 to 35,000 years old (France).

Having established, following the earlier work of Pederson & Scott (1951) who compared Eskimo teeth with those of American whites, that the vestibular dental surfaces of primitive meat eaters are more strongly grooved and have longer striations than those of populations which have a largely herbivorous diet, it is probable that the striations seen in this case result from a similar kind of processing prior to ingestion for Broken-Hill and Hortus men.

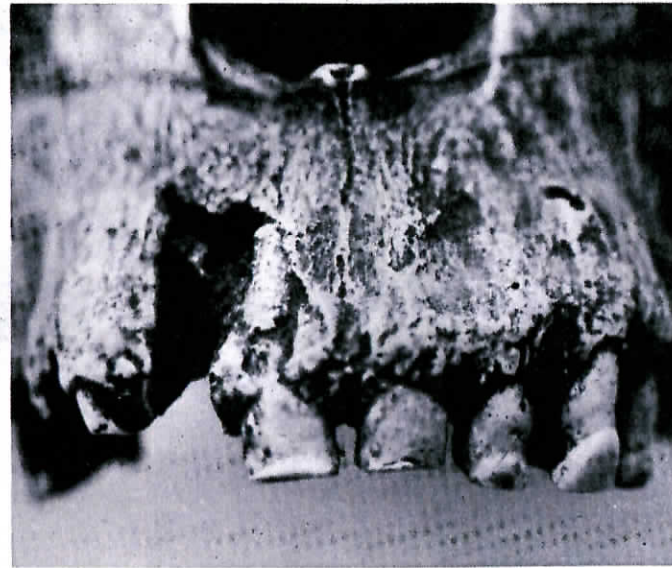
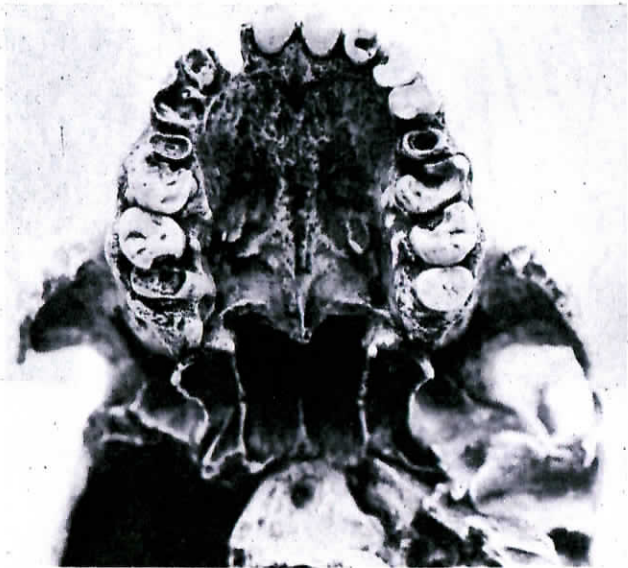


Plate 1. Broken-Hill man: the earliest evidence of human dental rampant caries 110,000 years ago.

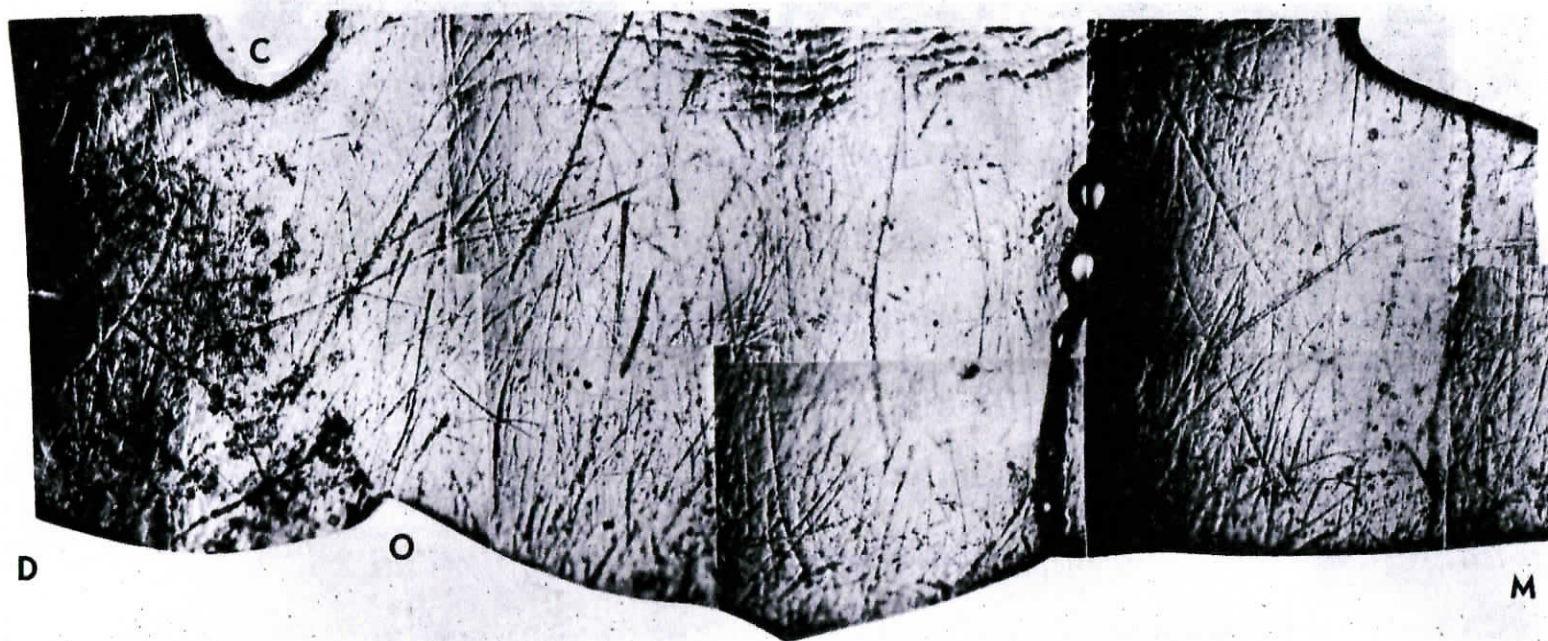


Plate 2. Tooth 16, striations of the buccal surface at a magnification
 $\times 50$.

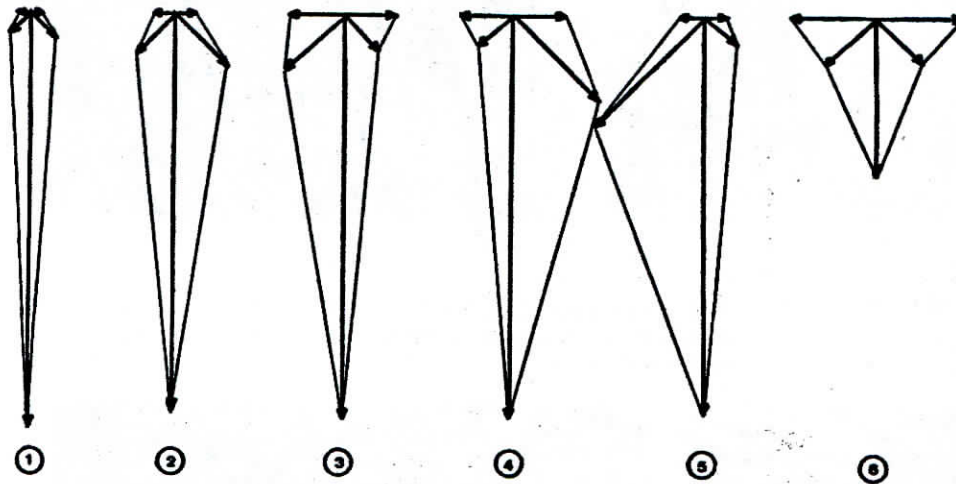
Plate 3. The canine 23 ($\times 50$) deep grooves are additional to the other striations, this is due to the use of the canine as a tool to assist the hands.



Plate 4. Occlusal molar surface no. 27 ($\times 50$) the cutting effect existed on the edges and has left deep parallel striations following a well defined direction.



Figure 2. Analysis of microscopic striations on the buccal surfaces of premolars and molars: the orientation of the microscopic striations was plotted, placing the total length of the grooves in any one direction on a star diagram, the degree of inclination varying from 45° to 45° . The average length of the striations was added to complete the description of the grooves. 1. A primitive meat eater, Vaimaca Peru (musée de l'Homme, Paris). Mean length of rays: 0.68 mm. 2. *Homo erectus* from Tautavel (450,000 B.P.). The microscopic striations are nearly all vertical and fairly long: 0.64 mm. 3. Neanderthal teeth from Hortus, France. There are more oblique and horizontal striations with an average length of 0.60 mm. 4. Broken-Hill man, Rhodesia. The majority of striations are vertical but the oblique striations are more numerous than for Tautavel man, suggesting a different alimentary regime. Mean length: 0.616 mm. 5. Bronze Age teeth from Peyrautes, France. The tendency towards mixed striations seen in the Neanderthal teeth increases. The average length is 0.54 mm. 6. A man who has had a largely herbivorous diet (no. 3503 Indian from Benares, musée de l'Homme, Paris). Mean length of rays: 0.46 mm.



The analysis of the occlusal surfaces of the incisors shows grooves oriented buccolingually. The lateral incisor, 22, has a majority of striations on the buccal face at a slightly oblique angle, running from back to front and from top to bottom relative to the longitudinal axis of the tooth. This orientation is due to the particular position of this tooth.

The canine, 23, shows predominantly vertical intersecting grooves on its buccal surface. This wear pattern is not related to cutting food, rather to the use of the canine as a tool to assist the hands. This is indicated by the deep grooves which are additional to the other striations and are oriented from both front to back and bottom to top (Plate 3).

The occlusal face of tooth 23 has a similar appearance to that obtained if attacked by acid. The surface shows the structure of the material and does not represent the history of life-time use. This is most likely due to the process of "cleaning" of the specimen either by the finder or by the archaeologists.

The wear pattern on the buccal surface of the premolar and the molars is fairly similar and consists of striations caused by the movement of the food ball compressed by the cheeks. The buccal surfaces can be divided horizontally into six as follows (Plate 2):

- (i) The first sixth consists of the rounded edge formed between the buccal and occlusal surfaces, used in a slicing action during lateral movements of the jaw.
- (ii) The next three-sixths form the main vestibular surface and the orientation of the striations gives evidence of the movement of food as a result of a churning action, producing a majority of vertical striations, the bolus being compressed on the dental surfaces by the cheeks.
- (iii) The last two-sixths, located below the curve of the tooth, are relatively protected from food abrasion and preserve their initial aspect.

The lingual surface can be divided in the same way but the action of the tongue has left curved striations.

The wear pattern on the occlusal surfaces reflects the different phases of the mastication process:

- (i) Polished surfaces occur where there are indentations caused through abrasion and erosion by food particles. These surfaces appear granular on magnification where erosion has attacked the dentine, either ante- or post-mortem.
- (ii) In this specimen, the cutting effect produced by the sliding action of opposed dental surfaces operating in a parallel direction to that of the plane of contact, existed only on the edges of the contact surfaces. This cutting action has left deep parallel striations following a well-defined direction (Plate 4).
- (iii) On the rest of the occlusal surfaces, the combination of crushing and cutting in the same grinding action has left fine striations following preferred directions.

No microscopic traces were found to indicate the use of tooth picks, nor was there any evidence of microscopic striations perpendicular to the longitudinal axis of the tooth in the area of the inter-proximal channels which, if present, would indicate deliberate removal of residual debris in the inter-dental spaces.

5. Conclusion

The suggested cause of rampant caries in Broken-Hill man is that he abandoned hunting in favour of vegetable foods and small animals during his retreat into the tropical forest. The distribution of microscopic striations on the dental surfaces indicate that the relation does not appear to be strong.

However it seems, given the inter-dental origin of the rampant caries and the absence of traces of tooth picks, that Broken-Hill man allowed the development of this decay through his ignorance of the use of tooth picks, which are known 300,000 years earlier as in the case of Tautavel man (France) and Atapuerca man (Spain). This lack of technical ability, which is even occasionally used by Chimpanzees (McGrew & Tutin, 1973), as well as a less favourable diet, could be related to an environmental change which Broken-Hill man was unable to adapt to, losing instead many of his established behavioural patterns. Such a regressive reaction is known from contexts in both human and animal behaviour (Alland, 1975). The idea put forward by some prehistorians (Constable, 1972) of a gourmet robbing the honey of wild bees, is no longer tenable, particularly in view of the studies of dental caries amongst the Egyptian Pharaohs (Storey, 1976).

The wear on the occlusal surfaces of the teeth of Broken-Hill man indicate that the advanced state of decay and lack of dental hygiene did not prevent him from growing

old, unless the caries appeared only a few years before death and the rate of decay was greatly accelerated.

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